NASA Procedures and Guidelines

NPG: 8020.12B

Effective Date: April 16, 1999
Expiration Date: April 16, 2001

Planetary Protection Provisions For Robotic Extraterrestrial Missions

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Responsible Office: S/Space Science

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TABLE OF CONTENTS

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Preface

P.1. PURPOSE

This document sets forth requirements applicable to robotic planetary flight programs. These requirements are necessary to enable the Associate Administrator for Space Science to fulfill those responsibilities pertaining to planetary protection, as stated in NASA Policy Directive NPD 8020.7E, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft, February 19, 1999. This document is specifically directed to (1) the control of terrestrial microbial contamination associated with robotic space vehicles intended to land, orbit, flyby, or otherwise be in the vicinity of extraterrestrial solar system bodies, and (2) the control of contamination of the Earth and Moon by extraterrestrial solar system material collected and returned by such missions.

P.2. APPLICABILITY

a. The provisions of this document apply to NASA Headquarters and NASA Centers, including Component Facilities, and to the Jet Propulsion Laboratory or other contractors as specified in the contract(s).

b. The requirements of this document apply to all robotic planetary flight activities with the exceptions listed below. The planetary flight activities include solar system exploration missions to the major planets as well as missions to planet satellites and to other solar system objects that may be of scientific interest.

c. This document is not applicable to the following:

(1) Terrestrial (Earth-orbiting) missions.
(2) Lunar missions.
(3) Human missions, except for Shuttle-launched, but otherwise robotic, planetary missions.

d. This directive applies to planetary flight programs and projects, and NASA officials having cognizance of such programs/projects will invoke these requirements in contractual instruments as may be appropriate to assure implementation.

P.3. AUTHORITY

NPD 8020.7E, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft, February 19, 1999, establishes the Agency's policy regarding the biological contamination control for outbound and inbound planetary spacecraft.

P.4. REFERENCES

None

P.5. CANCELLATION

This document cancels NHB 8020.12A, dated February 1976.

/s/ Edward J. Weiler
Associate Administrator for
Space Science

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CHAPTER 1. Introduction

1.1. Deviations

Each deviation from the requirements of this document is subject to the review and approval of the Planetary Protection Officer (PPO), NASA Headquarters. Procedures for requesting deviations are given in paragraph 2.4.

1.2. Relationship to Project Plan

a. NPD 7120.4A, "Program/Project Management," requires the preparation of a Project Plan during the genesis of any planetary flight project. The Project Plan should specify how the project will incorporate any required planetary protection planning. The scope of related information to be included and the level of detail will vary with each Project Plan but, in general, planetary protection planning should be described in a manner consistent with the overall scope of the planetary protection effort and with other elements of the Project Plan.

b. The Management Approach is a part of each Project Plan and should include the broad management aspects of the planetary protection activities of the project. Those major planetary protection planning documents that may be required, as specified in Chapter 2 of this document, should be referenced in the Project Plan.

1.3. Planetary Protection Classification of Missions

Each planetary mission will fall into one of five categories based on the planetary protection status of each extraterrestrial solar system body and the mission plan. Planetary protection priorities and corresponding mission categories are given in Table 1. Each category has different planetary protection requirements, as defined in Chapter 2 of this document.

Table 1. Planetary Protection Mission Categories

PLANET PRIORITIES		MISSION TYPE	MISSION CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted and no requirements are imposed.	Any except Earth return	I
B	Of significant interest relative to the process of chemical evolution	Any except Earth return	II

	but only a remote chance that contamination by spacecraft could jeopardize future exploration.		
C	Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return	V

CHAPTER 2. Requirements

2.1. General Mission Requirements

a. General planetary protection requirements applicable to each category of mission are shown in Table 2. Specific requirements for each planned mission will be determined by the NASA Planetary Protection Officer (PPO) in accordance with this document, and under the NASA accepted policy guidelines of the Committee on Space Research (COSPAR) of the International Council of Scientific Unions, and in consultation with the Space Studies Board of the National Research Council.

b. Requests for certification of missions as to category and specific requirements shall be submitted during the mission design phase (before the completion of the draft Planetary Protection Plan) by the mission Project Manager in letter or memorandum format, via the appropriate flight program manager, to the PPO. Such correspondence shall be accompanied by a mission description supplied by the Project Manager, and shall include a request and justification for a specific mission categorization. The PPO will respond in writing with the appropriate categorization, conveying such explanatory information or supplemental conditions as may be appropriate.

2.1.1 Requirements for NASA Instruments on Non-NASA Missions

a. Planetary Protection guidelines also are intended to apply to the flight of NASA instruments and/or experiments manifested on non-NASA spacecraft. NASA will approve the flight of NASA-developed instruments and/or experiments on non-U.S. planetary spacecraft if the mission adheres to approved planetary protection policy and requirements.

b. For flight on non-NASA spacecraft, NASA instruments and/or experiments will be delivered to the agency or project of the sponsoring organization or country in compliance with the applicable planetary protection requirements, and in a fashion compatible with specified subsequent planetary protection related procedures and activities.

c. For flight on non-U.S. spacecraft, the NASA instrument/experiment developer shall submit for approval, by the NASA PPO, a Planetary Protection Plan defining the planetary protection requirements to be implemented and outlining the general procedures to be employed to meet those requirements. Instrument projects anticipating flights on non-NASA spacecraft can receive preliminary guidance at any point by submitting a request to the PPO outlining the nature of the instrument(s) to be flown and details on the flight opportunity that is anticipated.

d. During development of the instruments/experiments the monitoring of the implementation of the planetary protection requirements will be the responsibility of the agency or project of the sponsoring country, unless NASA's PPO specifically agrees with the launching agency or project to share in, or assume, the

Table 2. Summary of Planetary Protection Requirements by Mission Category

CATEGORY	GENERAL REQUIREMENT	PAR.
I	Certification of Category I Mission	2.2.1
II	Documentation Only:	
	Planetary Protection Plan	2.3.1
	Prelaunch Planetary Protection Report	2.3.3
	Postlaunch Planetary Protection Report	2.3.4
	End-of-Mission Report	2.3.5
III	Implementing Procedures (as required):	2.2.3
	Trajectory Biasing	
	Clean Room Assembly	
	Microbial Reduction	
	Documentation:	
	Same as Category II, plus	
	Subsidiary Plans (as required)	2.3.2
IV	Implementing Procedures:	2.2.4
	Same as Category III, plus	
	Organics Inventory and Archive	
	Bioshield	
	Documentation:	
	Same as Category III	
V	Implementing Procedures:	
	Outbound:	2.2.5
	Per category appropriate to outbound mission	
	Inbound:	2.2.5
	Same as Category IV, plus	
	Continuing Monitoring of Project Activities	
	Preproject Advanced Studies and Research	
	Documentation:	
	Outbound:	2.3.6
	Per category appropriate to outbound mission	
	Inbound:	2.3.6.2
	Certification for "Unrestricted Earth Return"	
	Earth Safety Analysis Plan	

Earth Return Prelaunch Report
Earth Pre-Entry Report
Sample Prerelease Report
End-of-Mission Report

responsibility. Following delivery of the instruments/experiments, the agency or project of the sponsoring country is solely responsible for monitoring implementation of the applicable planetary protection requirements.

2.2. Implementation Requirements for NASA Missions

2.2.1. Category I Missions (no Planetary Protection (PP) Requirements)

Certification of a mission as Category I relieves a project of all further PP requirements, including documentation. Bodies typically not requiring planetary protection provisions include to and from the Earth's Moon, and missions to the Sun and Mercury.

2.2.2. Category II Missions

a. There are no formal implementation requirements for Category II missions beyond those needed to ensure that the mission is conducted as planned. The likelihood of accidental impact with a target planet should be minimized, and some contamination control measures may be required for probe and lander missions, if applicable.

b. Documentation requirements include a brief Planetary Protection Plan outlining intended or potential impact targets, brief Pre- and Postlaunch Planetary Protection Reports detailing impact avoidance strategies, and an End-of-Mission Report providing the final actual disposition of launched hardware and impact location (see paragraph 2.3). A written inventory of all organic materials (>1kg) carried aboard any Category II landed spacecraft may also be required as part of the Prelaunch Report.

2.2.3. Category III Missions

a. The implementation requirements for Category III missions comprise impact avoidance and contamination control. All Orbiter spacecraft and flyby modules shall be assembled in a Class 100,000 clean room or better using the attendant controls and procedures (see specification "Clean Room Requirement"). The probability of impact for launch vehicles must not exceed 10^{-4}. The probability of impact for a flyby module must not exceed 10^{-2}.

b. Orbiter spacecraft that achieve bioburden levels equal to the average total presterilization bioburden levels (surface, mated, and encapsulated) of the Viking landers shall not be required to meet impact or orbital lifetime requirements. The bioburden level requirement for Mars is noted in the specification "Orbital Lifetime, Mars." Achievement of these levels will likely require some form of active bioburden reduction. Bioassays are required to establish the bioburden levels. Assembled

spacecraft and all modules that have been bioassayed must be protected appropriately against recontamination.

c. Orbiter spacecraft that do not, or choose not to, achieve Viking lander average total presterilization bioburden level requirements, are required to meet a probability of impact requirement of 10^{-2} for a specified orbital lifetime limit (for Mars, see specification "Orbital Lifetime, Mars"). Mission compliance with these requirements will consist of probability-of-impact analysis, and orbital lifetime analysis. Trajectory biasing may be employed to lower the probability-of-impact of mission hardware, but is not required.

d. Typically the nature of contamination control for Orbiter spacecraft required to meet orbital lifetime requirements will be passive. That is, the cleanliness of the spacecraft may be inferred from acknowledgment of the efficacy of the standard procedures and methods employed and from prior facility verification. This validation will be sufficient to ensure compliance with the required constraints and provide the basis for indirectly predicting the expected levels of biological contamination using modeling techniques. The predictive tools employed must have the ability to assess and predict the contamination consequences in case of anomalous (unplanned) contamination events such as a clean room filter failure or a gross violation of personnel procedures. Cleaning procedures, with prevalidated contamination reduction effectiveness, may be needed and employed as appropriate in the event of such an occurrence. Adequate prevalidation and modeling will likely eliminate the need for direct biological reduction and evaluation of the vehicle.

e. The compliance documentation requirements include the following:

(1) A Planetary Protection Plan that must detail the planned approach to compliance with the implementation requirements,

(2) A Prelaunch Planetary Protection Report that must document the degree to which all requirements have been met,

(3) A Postlaunch Planetary Protection Report that must update the Prelaunch Planetary Protection Report,

(4) An End-of-Mission Report which provides a complete report of compliance, the final actual disposition of launched hardware, and in the case of accidental impact, the location of impact and an organics inventory. This inventory will include a list of bulk organic constituents (>1kg) of the spacecraft hardware and their mass. It will not include materials in small quantities or minute amounts of surface contaminants on the hardware. There is no requirement to maintain samples of any organic materials.

2.2.4. Category IV Missions

a. The implementation requirements for Category IV missions comprise the avoidance of non-nominal impact and bioburden control. Here, non-nominal impact denotes both

accidental impact by hardware not intended to directly contact the target planet and significant deviations from the plan by the other hardware systems. The total probability of any accidental impact by any hardware other than probe or lander modules must not exceed 10^{-4}.

b. Category IV consists of two subcategories, A and B. Category IV A missions, comprising landers and probes without life-detection experiments, must meet a bioburden limit specified for exposed surfaces. Category IV B, landers and probes with life-detection experiments[1], requires a more stringent bioburden limit and a complete system sterilization.

c. Bioburden control requirements include contamination control (minimum requirement = Class 100,000 clean rooms and attendant procedures; see specification "Clean Room Requirement"), microbiological assays, and maintenance of hardware cleanliness. Contamination control effectiveness must be monitored and demonstrated by periodic assays. These assays must also be employed to determine the hardware microbial burden. The project must provide the facility and the means to accomplish the system decontamination required for a Category IV B mission. For a Category IV A mission - only if needed to meet the burden requirement specifications, e.g. for a subsystem with a large surface area - the project must provide the facility and the means to accomplish a bioburden reduction. The facility will be subject to certification and the means of decontamination and/or bioburden reduction subject to approval and monitoring by the NASA PPO. Dry heat is the approved decontamination method, and specifications for its use are provided in appendix A. Alternative methods require a demonstration of effectiveness by the project and the approval of the PPO. Following the terminal microbiological assay and any microbial reduction procedure (as required), the project must demonstrate that the spacecraft (lander or probe) is adequately protected against recontamination. This may require the use of a bioshield or shroud. Whatever the means of protection, the project must provide demonstrated evidence that contamination requirements are not compromised following terminal treatment.

d. An organics inventory is required of the bulk (>1kg) organic constituents of all launched hardware which is intended to directly contact the target planet or which might accidentally do so. Each flight program office is to provide for the collection and storage, for at least 20 years from the launch of the spacecraft, of the following information and material:

(1) Parts lists, material lists, and other program documentation containing data relevant to organic material identification, which are prepared by a flight project to specify and control the materials that are included in a vehicle destined for planetary landing.

(2) A 50-gram sample of each organic compound used in a planetary lander vehicle that is present in total amounts exceeding 25 kg.

(3) The locations of landings and impact points of major components of space vehicles on the planet surface. Location(s) are to be determined and defined as accurately as mission constraints permit.

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[1]For the purposes of this requirement, a life detection experiment is defined as one whose life detection scientific objectives may be compromised by biological contamination. The arbiter of what constitutes life detection under this definition is the NASA PPO.

(4) Estimates of the condition of each landed spacecraft, to assist in calculating the spread of organic materials.

e. The documentation requirements include the following:

(1) A Planetary Protection Plan which must detail the planned approach to compliance with the implementation requirements (e.g., mission description, probability estimates, burden estimates, contamination analysis plan, assay plan, microbial reduction plan),

(2) A Prelaunch Planetary Protection Report which must document the degree to which all requirements have been met and must include the values of the microbial burden at launch and the organics inventory,

(3) A Postlaunch Planetary Protection Report which must update the Prelaunch Planetary Protection Report,

(4) An End-of-Mission Report which must provide a complete report of compliance and the final disposition of all launched hardware.

2.2.5. Category V Missions

The implementation requirements that relate to the protection of the target planet of a Category V mission (i.e., the outbound phase) are those of the Category appropriate to the mission if there were no Earth return phase.

2.2.5.1. Certification for "Unrestricted Earth Return"

a. Earth return missions certified for "unrestricted Earth return" have no other formal implementation requirements. Requests for certification as "unrestricted Earth return" must be submitted by the Flight Program Manager to the PPO when overall Categorization is requested.

b. After discussions with the PPO, a memorandum will be submitted by the Planetary Flight Program Manager to the Associate Administrator for Space Science, via the PPO, requesting "unrestricted Earth return" certification for the mission. Should this

certification be granted, then no further planetary protection requirements beyond those levied on the outbound phase of the mission will be levied. Missions not receiving this certification must comply with the documentation requirements set forth in the remainder of this section.

2.2.5.2. "Restricted Earth Return" Missions

a. For Category V missions not certified for "unrestricted Earth return," the highest degree of concern is expressed by the need for stringent measures to prohibit unplanned impact with the Earth, the need for sterilization of returned hardware which directly contacted the target planet, and the need for containment of any unsterilized sample collected there and returned to Earth. In general, this concern is reflected in a range of requirements that encompass those of Category IV, plus a continued monitoring of project activities and preproject studies and research (e.g., in remote sterilization procedures and containment techniques). Those requirements may affect all phases of the mission, namely the outbound leg; sample acquisition, transfer and storage; sealing of the sample container; monitoring of the sample; return phase of the mission; Earth entry phase; and sample receiving laboratory.

b. The documentation requirements for Category V missions include the following:

(1) A Planetary Protection Plan. If the mission is not certified for "unrestricted Earth return," the Planetary Protection Plan must also include an Earth Safety Analysis Plan.

(2) A Prelaunch Planetary Protection Report.

(3) A Postlaunch Planetary Protection Report.

(4) Reports analogous to the outbound phase launch: i.e., an Earth Prelaunch Report and an Earth Pre-Entry Report.

(5) A Sample Prerelease Report (see paragraph 2.3.6.2.d).

(6) An End-of-Mission Report with content appropriate to the mission category if no Earth return was planned. If the mission is not certified for "unrestricted Earth return," the End-of-Mission Report must address compliance with the requirements for the protection of Earth.

2.3. Planning and Documentation

Planetary protection documents shall be prepared as part of the formal documentation for the project and shall be submitted via the applicable Program Manager to the PPO for approval. Dates scheduled for drafts and formal submission of the required plans shall be per paragraph 2.6.

2.3.1. Planetary Protection Plan (Categories II-V)

2.3.1.1. General

Except for Category I missions, each planetary flight project shall prepare a Planetary Protection Plan according to the schedule outlined in paragraph 2.6.1.2. The Planetary Protection Plan shall be the primary planning document describing how a planetary flight project will be conducted so as to meet its planetary protection requirements. The Planetary Protection Plan shall indicate planned conformance to those requirements and shall include, as a minimum, the items given in the following outline. It is recognized that each project will prepare various other documents which may adequately cover some of the topics in the outline (e.g., the Project Plan may thoroughly cover the subject of Planetary Protection Management). In such instances,

it is suggested that the Planetary Protection Plan include only the major aspects of the topic and that free reference be made to the basic project documents which provide specificity.

A. General
   (1) Introduction
   (2) NASA Planetary Protection Constraints
      a. Identification of Mission Category
      b. Multi-Planet Missions*
      c. Planetary Protection Specifications

B. Planetary Protection Management and Organization
   (1) Organization Description
   (2) Responsibilities and Relationships
   (3) System Interface Management
   (4) Contractor Management
   (5) Data Management

C. Documentation
   (1) Identification of Basic Documents

D. Facilities
   (1) Identification of Controlled Facilities
   (2) Activities Performed
   (3) Hardware Affected

E. Schedules
   (1) Identification of Milestones
   (2) Tentative Schedules

In addition, the following subsidiary plans, as appropriate to the particular project, shall be prepared:

(1) Contamination Analysis Plan
(2) Microbiological Assay Plan
(3) Microbial Reduction Plan
(4) Earth Safety Analysis Plan

2.3.1.2. Mission Category Specific

a. For Category II missions, sections B (Planetary Protection Management and Organization) and D (Facilities) of the Planetary Protection Plan may be omitted (see paragraph 2.3.1.1). No subsidiary plans are required.

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* For multi-planet missions, a set of NASA planetary protection constraints will be specified for each involved planet. This will allow treatment of multi-planet missions as separate missions to each planet, for planetary protection purposes.

b. For Category III missions, all of the items listed in paragraph 2.3.1.1 shall be included. Subsidiary plans shall be provided as appropriate. Probability of impact and planned contamination control procedures should also be directly addressed in the Planetary Protection Plan for Category III missions. If the mission involves an orbiter, the minimum planned periapsis altitude and planned final disposition of the hardware must be noted.

c. For Category IV missions, all of the items listed in paragraph 2.3.1.1 describing the Planetary Protection Plan must be addressed. In addition, the Contamination Analysis Plan and the Microbiological Assay Plan (subsidiary plans) are required. If any microbial reduction procedures are contemplated, the Microbial Reduction Plan is also required. These subsidiary plans are described in paragraph 2.3.2.

d. Planning and documentation requirements for Category V missions, including required subsidiary plans, are described in paragraph 2.3.6.

2.3.2. Subsidiary Plans (Categories III-IV)

In addition to the Planetary Protection Plan, the following subsidiary plans shall be prepared as appropriate to the particular project.

2.3.2.1. Contamination Analysis Plan (Categories III and IV)

This document shall be the primary planning document covering the major analyses which are performed by the project and ultimately used to demonstrate to the PPO that the project is meeting the planetary protection requirements on microbial burden, as appropriate. This plan should include, but not be limited to, the subjects given in the following outline:

A. General

(1) Introduction
(2) Rationale

B. Potential Contaminating Sources

C. Microbial Burden Estimate Model
(1) Contamination Sources Analysis
a. Analytical Techniques
b. Assumptions
c. Substantiation of Parameter Values
(2) Microbial Burden Allocation Model
a. Systems Allocations (Spacecraft, Launch Vehicle, etc.)
b. Subsystem and Lower Level Allocations

D. Analysis Documentation

2.3.2.2. Microbiological Assay Plan (Category IV)

a. The Microbiological Assay Plan shall identify the space vehicle hardware, facilities, and associated environments which are to be subject to microbiological assay, and shall describe the rationale, concepts, and detailed procedures pertaining to such assays. The plan also shall describe the microbiological quality assurance procedures used to ensure validity of the assay results.

b. The plan shall include, but not be limited to, the subjects given in the following outline:

A. General
(1) Introduction
(2) Rationale

B. Assay Methods
(1) Utilization of NHB 5340.1B ("NASA Standard Procedures for the Microbiological Examination of Space Hardware"). Alternative procedures, consistent with mission and life detection objectives, may be proposed by the Project for approval by the PPO
(2) Assay Laboratory Procedures
(3) Sampling Procedures
(4) Provision for Primary Assays
(5) Quality Assurance Provisions

C. Facilities
(1) Controlled Facilities
a. Assay Laboratories
b. Hardware Areas

(2) Uncontrolled Facilities
    a. Monitoring
    b. Environmental Estimates

D. Space Hardware (Flight) Assay and Control
(1) Identification
(2) Hardware Exceptions
(3) Contingency Planning

E. Assay Data
(1) Traceability
(2) Analysis and Interpretation
(3) Management and Handling

2.3.2.3. Microbial Reduction Plan (Category IV)

A Microbial Reduction Plan shall be submitted for robotic planetary missions involving hardware elements that must have their biological load reduced to a specified or measured (assayed) level. This requirement should not be construed to apply to situations involving simple wiping or cleaning procedures that are performed on a "best effort" basis, even though such procedures may have as their objective the reduction of microbial load. The Microbial Reduction Plan shall include, but not be limited to, the subjects in the following outline:

A. General
(1) Introduction
(2) Rationale

B. Spacecraft Hardware Subject to Microbial Reduction Processes
(1) Identification
(2) Exceptions

C. Process Analysis
(1) Analytical Techniques
(2) Assumptions
(3) Process Parameters
(4) Process Modification

D. Process Verification and Control
(1) Process Description and Boundaries
(2) Process Qualification
(3) Equipment and Facilities Qualification
(4) Acceptance Criteria
(5) Process Interruption and Modification
(6) Quality Assurance Provisions

E. Maintaining Reduced Microbial Level

(1) Monitoring/Assay
(2) Use of Microbial Barriers
(3) Macro-organism (Insect, Animal, etc.) Control
(4) Contingency Planning

2.3.3. Prelaunch Planetary Protection Report

2.3.3.1. General

a. This shall be the basic document used by a flight project to provide verification to the PPO that planetary protection requirements have been met (to the issue date of the document) and that the project can continue to satisfy them throughout the mission.

b. This document shall include, but not be limited to, the following information which may be included as an integral part of the document, or may be included in separately published documents which are referenced in the basic document. Separately published documents may be submitted to the PPO as they are published, with notification that such documents are to constitute a part of the "Prelaunch Planetary Protection Report." Required information is as follows:

(1) A demonstration that all planetary protection constraints and requirements as noted in the Planetary Protection Plan will be met.

(2) Identification of all deviations (see paragraph 2.4) from the Planetary Protection Plan.

(3) Summaries of significant potential violations of planetary protection which could occur in the sequence of events remaining until mission completion; discussion of contingency planning associated with each event.

2.3.3.2. Mission Category Specific

a. For Category II missions, a report on contamination control measures (if any), and any required organic inventory shall also be provided.

b. For Category III missions, the following information shall also be reported:

(1) Calculations of microbial burden estimates.

(2) Report on required contamination control measures.

(3) Calculations of probability of impact.

b. If the mission involves the use of hardware subject to microbial reduction processes, the verification that such processes have been properly applied must be included. If the mission involves an orbiter as part of the launched hardware, the issue of orbital lifetime shall also be addressed.

c. For Category IV missions, the requirements include the same information as for Category III. Additionally, an inventory of the organic materials contained in any spacecraft hardware intended to encounter high-priority planet(s) must also be included. This inventory must also be submitted for missions whose hardware may possibly encounter high priority planet(s).

2.3.4. Postlaunch Planetary Protection Report

After the launch of a planetary vehicle, the flight project shall submit to the PPO a "Postlaunch Planetary Protection Report." This shall be a brief summary document based on the "Prelaunch Planetary Protection Report" but updated to include the effects of launch and early postlaunch events. It shall indicate the degree to which the mission meets the overall planetary protection requirements through these early mission events.

2.3.5. End-of-Mission Report

a. At the formally declared "end-of-mission," a report shall be provided which documents the degree to which the mission has met the PP requirements throughout the complete mission and reports on final disposition of all launched hardware.

b. For all Category II and III missions, an inventory of organic materials must also be provided in the End-of-Mission Report for any spacecraft hardware which unintentionally impacts any solar system body.

2.3.6. Category V Missions, Planning, and Documentation

2.3.6.1. Outbound

For the outbound phase of Category V missions, the planning and documentation requirements are those appropriate to the mission if there were no Earth-return phase.

2.3.6.2. Inbound

Earth return missions certified for "unrestricted Earth return" have no other formal implementation requirements. Missions not so certified will complete the following:

a. Earth Safety Analysis Plan

This document shall be the primary planning document covering the Earth-return portion of the mission to demonstrate to the PPO that the project is meeting its planetary protection requirements. This plan should include, but not be limited to, the subjects given in the following outline:

A. General
   (1) Identification

(2) Rationale

B. Potential Contaminating Sources
(1) Sample Containment Approach
(2) Decontamination Approach (if any)
(3) Earth Entry Plan

C. Probability of Contamination Model
(1) Mission Probability of Contamination Equation
(2) Critical Parameters
(3) Contamination Sources Analysis
a. Analytical Techniques
b. Assumptions
c. Substantiation of Parameter Values
(4) Probability of Contamination Allocation Model
a. Level of Risk (provided to the Project by the PPO)
b. System Allocations (Return Capsule, Return Vehicle, etc.)

D. Analysis Documentation

b. Earth Return Prelaunch Report

The "Earth Return Prelaunch Report" shall be the document used by a flight project to provide verification to the PPO that planetary protection requirements outlined in the Earth Safety Analysis Plan have been met and that the project can continue to satisfy them throughout the Earth-return portion of the mission.

c. Earth Pre-Entry Report

After the launch of a planetary vehicle, the flight project shall submit to the PPO an "Earth Pre-Entry Report." This shall be a summary document based on the "Earth Return Prelaunch Report," but updated to include the effects of launch and early postlaunch events. It shall indicate how the mission meets the overall planetary protection requirements.

d. Sample Prerelease Report

Before an extraterrestrial sample is released to the general scientific community for investigation, a "Sample Prerelease Report" shall be issued to provide verification that the sample will not harm the Earth's biosphere.

e. End-of-Mission Report

At the formally declared "end-of-mission," a report shall be provided which documents the degree to which the mission has met the planetary protection requirements throughout the complete mission. Special attention shall be paid to Earth safety requirements.

2.4. Requests for Deviations

a. Deviations from the requirements of this document may be sought by including proposed alternatives as a distinct, separately identified, part of the Planetary Protection Plan (or other applicable Subsidiary Plan). Approval of Plans by the PPO will constitute approval of deviations so incorporated.

b. Deviations which are sought subsequent to the formal approval of the Planetary Protection Plan (or other applicable subsidiary plans) may be requested by petitioning the PPO in writing. Such petitions shall be transmitted via established program management channels. Requests shall describe the need for a deviation and the justification to support the request, including the impact of the requested change on the original analyses and resulting changes, if any, in the category of the mission. The degree of compliance with all requirements shall also be addressed. This requirement also shall apply to postlaunch changes (see paragraph 3.1.5.2). Responses to each request will be made in writing by the PPO. Certification changes within Category V will require approval by the Associate Administrator for Space Science.

2.5. Reviews

2.5.1. General

a. In order to assure that planetary protection activities are proceeding properly, the various review actions specified in paragraph 2.5.2 through 2.5.4 shall be accomplished as a minimum for Category III and IV missions. All of these reviews shall be held for Category V missions not certified for "unrestricted Earth return."

b. Generally, it is the intent that planetary protection activities be reviewed at the time of project reviews of progress in other technical areas. As an alternative to conducting the separate reviews specified in paragraphs 2.5.2 through 2.5.7, a project may incorporate the specified reviews as a segment of broader project reviews.

c. The PPO, or designee, shall be in attendance at these reviews. The date scheduled for each specified review (excluding the Launch Readiness Review) shall be per paragraph 2.6.

2.5.2. Project Planetary Protection Planning Review (Categories II-V)

a. At the request of either the PPO or the project, a Planetary Protection Planning Review may be held when the draft version of the project's Planetary Protection Plan and the subsidiary plans are near completion. The purpose of conducting this review at this time would be to enable the PPO to suggest such changes to the project's planetary protection planning as are necessary for the formal version of the Planetary Protection Plan to be approved without major change or delay.

b. The content of this review should be developed from discussions between the PPO and various organizational elements of the project. Action items which may result from

this review shall be followed and closed out by the same procedures the project uses for resolving action items resulting from other formal technical reviews. The PPO may require that all action items resulting from this review be closed out before formal approval of the Planetary Protection Plan. Approval of the mission's Planetary Protection Plan constitutes formal categorization of the mission for planetary protection purposes.

2.5.3. Prelaunch Planetary Protection Review (Categories III-V)

Prior to launch, a "Prelaunch Planetary Protection Review" shall be conducted for all missions assigned to Categories III, IV, and V. The PPO shall conduct this review to ascertain that a project has, to that date, met its planetary protection requirements, and to examine in detail the planetary protection activities accomplished prior to this review, as well as those remaining up to launch. The "Prelaunch Planetary Protection Report" (see paragraph 2.3.3) shall form the framework for this review.

2.5.4. Launch Readiness Review (Categories III-V)

Various events detrimental to planetary protection could occur subsequent to the Prelaunch Planetary Protection Review and prior to actual launch of the vehicle. In order to assure that planetary protection requirements continue to be met, the PPO (or designated alternate) shall participate in the project's formal Launch Readiness Review, the agenda of which shall include planetary protection as a topic. Significant planetary protection events, problems, changes, open action items, etc., which have occurred since the Prelaunch Planetary Protection Review, shall be addressed.

2.5.5. Earth Return Prelaunch Review (Category V)

Prior to launch of the Earth return portion of a Category V mission, an Earth Return Prelaunch Review shall be conducted for all missions assigned to Category V. The PPO shall conduct this review to ascertain that a project has, to that date, met its planetary protection requirements and to examine in detail the planetary protection activities accomplished prior to this review, as well as those remaining up to launch. The formally released edition of the document "Earth Return Prelaunch Report" (see paragraph 2.2.6.2.3) shall form the framework for this review.

2.5.6. Earth Safety Analysis Review (Category V)

Prior to committing a spacecraft to the Earth return portion of its mission, all Category V missions (other than those certified for "unrestricted Earth return") shall conduct an Earth Safety Analysis Review to determine that all planetary protection requirements have been met and will continue to be met throughout the duration of the mission. The formally released document "Earth Safety Analysis Plan" (see paragraph 2.3.6.2.1), as updated by the Earth Return Prelaunch Report, shall form the framework for this review.

2.5.7. Returned Sample Release Review (Category V)

Prior to release of an extraterrestrial sample to the general scientific community, all Category V missions shall conduct a Returned Sample Release Review. This review is to determine that all planetary protection requirements have been met. The formally released document "Sample Prerelease Report" (see paragraph 2.3.6.2.d) shall form the framework for this review.

2.6. Schedules

The dates scheduled for planetary protection plans, reviews, and documentation are intended to be established so as to be mutually acceptable to the flight project and the PPO. It is also the intent that the established dates be considered control items to be reported in the monthly Project Management Reports (PMR's). In lieu of the development of mutually acceptable schedules, the following schedules shall apply.

2.6.1. Plans and Other Required Documents

2.6.1.1. Certification of Category I Missions

The flight program manager shall submit to the PPO a request for certification to Category I no later than the end of Phase A of missions intended to be certified as Category I.

2.6.1.2. Planetary Protection Plan

The draft version of the Planetary Protection Plan shall be completed no later than the end of the project's conceptual study phase (phase B1). The release (see Glossary) of the Planetary Protection Plan shall be no later than the project's Preliminary Design Review.

2.6.1.3. Subsidiary Plans

Draft versions of required subsidiary plans shall be completed no later than 3 months after completion of the draft version of the Planetary Protection Plan. The release of all subsidiary plans shall be before, or in conjunction with, the Project Detail, or Critical Design Review.

2.6.1.4. Certification for "Unrestricted Earth Return"

The flight program manager shall submit a request for certification for "unrestricted Earth return" to the Associate Administrator for Space Science, via the PPO, no later than the end of Phase A of missions intended to be certified for "unrestricted Earth return."

2.6.1.5. Prelaunch Planetary Protection Report

This document shall be released no later than 90 days prior to launch.

2.6.1.6. Postlaunch Planetary Protection Report

This document shall be released within 60 days after launch.

2.6.1.7. End-of-Mission Report

This document shall be released within 60 days after the formally declared "end-of-mission."

2.6.1.8. Earth Return Prelaunch Report

As required, this document shall be released prior to the conduct of the Earth Return Prelaunch Review.

2.6.1.9. Earth Pre-Entry Report

As required, this document shall be released prior to the conduct of the Earth Safety Analysis Review.

2.6.1.10. Sample Prerelease Report

As required, this document shall be released prior to the conduct of the Returned Sample Release Review.

2.6.2. Reviews

2.6.2.1. Planetary Protection Plan and Subsidiary Plans

Review of the Planetary Protection Plan and subsidiary plans shall be held within 60 days of the release of the draft version of these plans, and a formal review may be held at the request of either the PPO or the project.

2.6.2.2. Prelaunch Planetary Protection Review

The Prelaunch Planetary Protection Review shall be held no less than 90 days nor earlier than 120 days prior to the earliest scheduled launch date.

2.6.2.3. Launch Readiness Review

This is a project-scheduled review and no planetary protection schedule requirements are imposed.

2.6.2.4. Earth Return Prelaunch Review

The Earth Return Prelaunch Review shall be held no less than 24 hours nor earlier than 3 days prior to the earliest scheduled launch date.

2.6.2.5. Earth Safety Analysis Review

The Earth Safety Analysis Review shall be held no earlier than 30 days prior to, nor later than, commencement of the Earth insertion orbit.

2.6.2.6. Returned Sample Release Review

The Returned Sample Release Review shall be held no later than 30 days after return of hardware and prior to any sample release.

CHAPTER 3. NASA Constraints

3.1. General

The following planetary protection constraints, as may be applicable to each mission, are imposed on robotic planetary flight projects. Specific exceptions to these constraints may be sought by a flight project in accordance with the provisions of paragraph 2.4.

3.1.1. Specification of Parameters

a. In order for a flight project ultimately to demonstrate compliance with planetary protection requirements, various pertinent parameters and specifications (such as the burden requirement for a mission type to a given target planet) will be specified by the PPO at the initiation of the project. Each major parameter and specification will be defined and its value specified on a "Parameter Specification Sheet" which will be valid when dated and authorized by the signature of the PPO. Flight projects may use applicable values specified therein without further authorization. Deviations from specified values shall be handled per paragraph 2.4. All approved Planetary Protection parameter specifications are included in appendix A.

b. The values adopted by a project for unspecified parameters and specifications are subject to the approval of the PPO. These project-developed parameters and specifications will appear in the "Planetary Protection Plan," with late changes thereto in the "Prelaunch Planetary Protection Report." Approval of these documents will constitute approval of the parameters and specifications. Alternately, during the course of a project, a project may request the PPO to issue appropriate Parameter Specification Sheets based on available information and data.

c. In addition to the primary purpose of specifying parameters and specifications used in mission planning, Parameter Specification Sheets also may be used for other purposes, such as to specify contamination-related process parameters (e.g.: minimum temperature for microbial reduction processes, etc.).

3.1.2. Microbial Reduction

3.1.2.1. Microbial Reduction for Planetary Spacecraft (Including Capsules and Probes)

a. Microbial reduction for an entire planetary spacecraft (including planetary entry probes and planetary landing capsules) may be accomplished by any qualified process. A significant microbial reduction can be achieved by the use of a specified elevated temperature of a gaseous atmosphere of specified composition (including water vapor) for a specified length of time. This is commonly referred to as a "dry heat" cycle and shall be considered the preferred method for conditioning spacecraft to a sterile or near-sterile environment.

b. Alternate methods of microbial reduction may be proposed, such as by chemical or radiative techniques, or various combinations thereof with heat. Acceptance of such methods will be based on a rigorous examination of data supplied which must demonstrate conclusively the biological effectiveness and reproducibility of the alternate method for the specific application under consideration, while not imposing an undue reduction of the reliability of the hardware to be subjected to the process.

c. In no case shall basic parameters of microbial reduction processes (e.g., temperature, radiation type, etc.) be made binding in contractual instruments or governing project documents without documented approval of these parameters by the PPO. The specification of these basic parameters will be made normally in (1) the Microbial Reduction Plan, (2) Parameter Specification Sheets, or (3) contractor-prepared documents submitted for project approval; approval of these documents by the PPO will constitute the aforementioned "approval of parameters."

3.1.2.2. Calculation of Microbial Reduction Processes

a. Validity of Parameter Values

Parameter values, other than those specified in applicable Parameter Specification Sheets, which are used in calculating microbial reduction process cycles, shall be supported by reproducible laboratory tests or by suitable technical references.

b. Estimation of Surviving Microorganisms

A calculation of the microbial reduction produced by a given process cycle shall show that the predicted number of microorganisms surviving the process is not more than the acceptable value as given in the "Prelaunch Planetary Protection Report."

c. Microbial Reduction Temperature Constraints

For those microbial reduction process cycles which utilize transient temperature lethality effects, the "dry heat" temperature used to begin lethality calculations shall be stated in a Parameter Specification Sheet. The minimum steady-state temperature of the dry heat cycle shall not be less than that specifically stated in either the Microbial Reduction Plan or in a Parameter Specification Sheet.

3.1.2.3. Verification of Microbial Reduction

Verification that a spacecraft has achieved the required degree of microbial reduction shall not require microbiological assay of the interior of the spacecraft subsequent to the application of the microbial reduction process. Each spacecraft will be considered to have met its microbial reduction requirement provided that the following occurs:

a. Tests, or analyses based on tests, demonstrate that the application of the microbial process cycle to the spacecraft produces the microbial reduction required by the "Prelaunch Planetary Protection Report."

b. The biological populations of the spacecraft prior to the application of the microbial reduction process have been estimated (by means acceptable to the PPO) to be within limits that will allow the planned microbial reduction process to be adequate.

c. It has been verified that the specified microbial reduction process cycle physical parameters, such as time, atmospheric composition (including water vapor), and temperature, have been properly imposed on the spacecraft.

3.1.2.4. Microbial Reduction of Planetary Spacecraft Parts, Components, and Subsystems

To reduce the severity of a microbial reduction process to be applied to the entire spacecraft, it may be desirable to subject either all or certain elements of hardware to a microbial reduction process prior to their assembly into a planetary spacecraft. Microbial reduction of such hardware (while at a level of assembly lower than that of a complete spacecraft) may be accomplished by methods other than those used for the entire spacecraft, provided that the following occurs:

a. A statement is made in the Microbial Reduction Plan that it is planned to utilize unique microbial techniques or processes different from those applied to such hardware during the microbial reduction of the entire spacecraft.

b. Each unique microbial reduction technique or process cycle to be used is described in a process of specification which includes the biological qualification and quality assurance requirements applicable to the process.

c. The detail specification covering each item of hardware to be processed cites, as an applicable document, the unique process specification to be used.

d. The unique microbial reduction techniques or process cycles employed do not degrade the ability of the spacecraft to withstand the standard "dry heat" or other approved process cycles to be applied to the entire spacecraft.

3.1.2.5. Use of Microbial Barriers

Preplanned operations involving the use of microbial barriers after microbial reduction processes have been conducted may be proposed as an intrinsic part of the Planetary Protection Plan or Subsidiary Plans. If the use of microbial barriers is proposed, the appropriate plan shall describe the operation and qualification of both the hardware and techniques to be used.

3.1.3. Microbiology Constraints

3.1.3.1. Death Rate of a Population of Microorganisms

Calculations involving the death of microorganisms subjected to a lethal condition shall be based on a death rate model approved by the PPO.

3.1.3.2. Microbiological Assay

The procedures to be used for the microbiological assay of planetary vehicle hardware and the environments affecting the condition of such hardware shall be as defined in the current version of NHB 5340.1B, "NASA Standard Procedures for the Microbiological Examination of Space Hardware," as modified and supplemented by the project's "Microbiological Assay Plan." The version of the NHB 5340.1B which is to be effective for a particular planetary program shall be specified in the applicable Microbiological Assay Plan. Alternative assay procedures, consistent with mission and life detection objectives, may be proposed by the Project for approval by the PPO.

a. Microbiological Assays in Support of the Planetary Protection Officer (PPO)

(1) In addition to those microbiological assays which a flight project organization or its contractors may wish to conduct, various "primary" assays (see Chapter 5) will be conducted for the PPO by an organization designated by the PPO. Primary assays may be observed by involved flight project and contractor organizations.

(2) Microbiological samples (e.g., of spacecraft hardware, assembly facility environment, etc.) shall be furnished to the PPO by the flight project (or contractors) in accordance with the quantity and locations given in the Microbiological Assay Plan. Collection of microbiological samples may, at the option of the PPO, be subject to observation by the PPO or designated representative. The microbiological samples (furnished by the flight project) will be processed to obtain such assay data as are believed to be pertinent including, for example, microorganism types and numbers.

(3) In the event that certain assay data are suspect due to possible laboratory contamination, an Assay Review Board shall be formed to review the suspect data and its causes. This Board shall be chaired by the PPO, or designee, with members representing both the assay organization and the involved flight project, and such other members as appropriate to provide technical review of the matter. The Board shall present its findings and conclusions to the PPO together with appropriate recommendations.

3.1.4. Microbial Barrier Constraints

The following constraints apply to the design and operation of spacecraft microbial barriers:

a. Microbial barriers which are continuously maintained at a static pressure of at least 1244 pascals (9.3 Torr; 5 inches of H_2O) above the ambient pressure shall be considered microbiologically sealed.

b. Microbial barriers which operate essentially at ambient pressure through the use of microbial filters shall be considered microbiologically sealed, provided that the following occurs:

(1) The designs of all filter mountings, barrier joints, seals, etc., have been tested in accordance with applicable design and test specifications, and found capable of retaining 99.97 percent of all particles or organisms greater than 3 x 10-7 meters in size.

(2) The filter media are High Efficiency Particulate Air Filters ("HEPA Filters") capable of removing 99.97 percent of all particles greater than 3 x 10-7 meters in size.

(3) All elements of the filter system are procured, installed, tested, inspected, and maintained under specifications containing appropriate quality assurance provisions.

3.1.5. Launch and Postlaunch Operations Constraints (Categories III-V)

3.1.5.1. Launch Operations Constraints

To assure that planetary protection requirements are met through launch and until the spacecraft leaves the atmosphere, the PPO, or designated representative, will be present at the launch site during launch operations. As a part of launch operations, the PPO shall verify that planetary protection requirements have been met and that the mission, from a contamination viewpoint, may be launched. To provide a basis for this judgment, the project shall make available to the PPO pertinent information and documentation generated since the Prelaunch Planetary Protection Review and the Flight Project Readiness Review, as well as real-time information relevant to planetary protection aspects of launch operations.

3.1.5.2. Postlaunch Changes

Changes from the original mission plan which become necessary as a result of postlaunch anomalies shall be approved by the PPO before implementation, if such changes potentially could affect the probability of planetary contamination.

CHAPTER 4. Management

4.1. Project Plan

The management relationships established for the conduct of a specific planetary project will be as described in the applicable Project Plan. Each planetary flight mission Project Plan will be reviewed by the PPO to assure that management relationships permit the Associate Administrator for Space Science to fulfill his/her responsibilities as identified in NPD 8020.7E.

4.2. Responsibilities of the Planetary Protection Officer (PPO)

The responsibilities delegated by the Associate Administrator for Space Science to the PPO are identified in NPD 8020.7E. In discharging those responsibilities, the PPO will accomplish the following:

a. Represent the Associate Administrator for Space Science in external technical activities in the area of planetary protection. This includes consultation with other U.S. Government agencies, and, in coordination with the NASA Office of the General Counsel and the NASA Office of External Relations, with representatives of other nations, and with international bodies such as the Committee on Space Research of the International Council of Scientific Unions.

b. Maintain liaison with the secretariat and members of the Space Studies Board of the National Research Council to inform them of the NASA planetary protection policy and major actions, and seek to engage their participation.

c. Establish planetary protection requirements applicable to each planetary flight program/project; coordinate and interpret these requirements with appropriate representatives of the planetary flight program and project offices; establish methods to verify that planetary protection requirements have been met.

d. Provide support to planetary flight program/project offices in the following areas, as may be agreed to by the appropriate flight program and project managers and the PPO:

(1) Preparing guidelines which supply data, procedural techniques, document interpretation, amplification of requirements, and other such information that may be useful to the flight program/project in meeting planetary protection requirements.

(2) Reviewing, concurring, or approving procedures, standards, specifications, and other documents used to control factors impacting planetary protection.

(3) Providing for the performance of biological assays to supplement those performed by a flight program/project, if applicable.

(4) Coordinating closely with flight program/project activity by providing recommendations and guidance.

e. Provide oversight of flight program/project activities as required to ascertain the extent of flight program/project adherence to established planetary protection requirements. This may involve the following:

(1) Performing primary assays (see Chapter 5) of environments, facilities, and flight hardware independent of assays conducted by flight programs/ projects.

(2) Monitoring records and data generated by a flight program/project which are used to comprise verification of having met planetary protection requirements.

(3) Witnessing significant development and qualification tests and flight program/project operations to verify conformance with approved procedures and plans.

CHAPTER 5. Glossary

Biological Monitoring. The data management and visual surveillance activities which are performed so that the biological condition of an item of interest may be verified.

Microbial Barrier. A barrier surrounding a spacecraft or capsule which prevents biological contamination of the spacecraft or capsule subsequent to microbial reduction procedures.

Microbial Assay. That group of activities concerned with obtaining microbial data, usually by sampling techniques, which are used to derive an estimate of the number or kind of microorganisms associated with an item of interest.

Planetary Protection. The avoidance of contaminating a planet (the term "planet" is used here with its broadest applicability, as explained in P.2) with foreign life forms so that the planet is maintained in its pristine state during the period of scientific investigation. The avoidance of contaminating the Earth's biosphere with extraterrestrial agents that might have a deleterious effect.

Primary Assay. A microbiological assay performed as designated by the PPO in accordance with laboratory procedures approved by the PPO for each specific assay.

Release (as applied to the state of a document). The affixation of all signatures required to authorize the document as one which is applicable to the project. Distribution of document as part of official policy, inside and outside NASA, as appropriate.

Appendix A: Planetary Protection Parameter Specification Sheets

TABLE OF CONTENTS

PARAMETER TITLE: Clean Room Requirement

VALUE	
UPPER	
ACCEPTABLE	Class 100,000
LOWER	

APPLICATION	
MISSION	
CATEGORY	III and IV
PLANET	All

PARAMETER DEFINITION: Procedures for spacecraft and payload assembly.

APPLICABLE SOURCE: Spacecraft and payloads.

CONSTRAINTS: All Category III and IV missions shall assemble and maintain spacecraft and payloads in Class 100,000 clean rooms, in the operational mode (Ref. 1). The class is to be monitored and verified, with the sampling frequency and number of locations per a clean zone as specified in Ref. 1 for any flight hardware location within the clean room. Attendant controls and procedures must be similar to those employed by the Viking Project. This requirement is independent of any other requirement, e.g., any bioburden limitation.

REFERENCES: 1. "Clean Room and Clean Work Station Requirements, Controlled Environments", Federal Standard No. 209C, 1987 (or latest revision).

_____ _____

Planetary Protection Officer Date

PARAMETER TITLE: Maximum Probability of Accidental Impact, Category III (P_I, max (III))

VALUE	
UPPER	10^{-2}
ACCEPTABLE	10^{-2}
LOWER	10^{-2}

APPLICATION	
MISSION	Orbiter, Flyby
CATEGORY	III
PLANET	

PARAMETER DEFINITION: The maximum allowable probability of accidental impact of a Category III mission.

APPLICABLE SOURCE: All Category III flyby and orbiter spacecraft and other associated hardware.

CONSTRAINTS: The project will conform to Class 100,000 contamination control . For a Category III orbiter, the value must not be exceeded for the period of orbital lifetime required. Launch vehicles must meet a 10^{-4} requirement.

Planetary Protection Officer	Date

PARAMETER TITLE: Average Encapsulated Microbial Density $\left(\bar{d}_V(0)\right)$

VALUE	
UPPER	$130/cm^3$
ACCEPTABLE	$130/cm^3$
LOWER	$130/cm^3$

APPLICATION	
MISSION	All
CATEGORY	III, IV
PLANET	All

PARAMETER DEFINITION: The average density of spores buried inside non-metallic spacecraft material. This value reflects reductions experienced in the manufacture of the basic material but it does not account for any burden reduction during higher level assembly and test.

APPLICABLE SOURCE: Non-metallic portions of the spacecraft.

CONSTRAINTS: If this parameter is used, it must be applied to the total volume of non-metallic material and further subdivisions using source-specific density values $d_V^i(0)$ shall not be made.

This value was derived assuming the subsequent use of heat sterilization. If processes are proposed that do not include heat for a Category IV mission, the value must be reassessed to assure its applicability for the proposed usage. It may be used without restriction for Category III mission burden estimates.

REFERENCES: Planetary Quarantine Advisory Panel (PQAP) Review, September 28, 1971, Denver, Colorado.

Planetary Protection Officer	Date

PARAMETER TITLE: Source Specific Encapsulated Microbial Density $\left(d_V^i(0)\right)$

VALUE	
UPPER	
ACCEPTABLE	See Below
LOWER	

APPLICATION	
MISSION	All
CATEGORY	III, IV
PLANET	All

PARAMETER DEFINITION: The average number of spores buried inside the i^{th} subassembly or component of a spacecraft. The number can be expressed in terms of volume or area according to the application as specified below.

APPLICABLE SOURCE: Non-metallic materials on the spacecraft.

CONSTRAINTS: Source-specific density values can be used only if applied to the entire volume of spacecraft non-metallic material without resorting to the average density value, $d_V(0)$, for any portion thereof. Values for this parameter must be derived for all applicable sources. Values are selected from the following categories and ranges depending upon the composition of, and manufacturing process for, each designated source:

Encapsulated Organisms in:	$d_V^i(0)$
Electronic piece parts	3-150/cm^3
Other non-metallic materials	1-30/cm^3

Enclosed surface densities:

Clean room-highly controlled	0.05-0.5cm^2
Clean room-normal control	0.5-10/cm^2
Uncontrolled manufacturing	10-100/cm^2

In the use of this parameter a rationale shall be presented for the selection of values less than the maximum of the applicable range specified. This value was derived assuming the subsequent use of heat sterilization. If processes are proposed that do not include heat for a Category IV mission, the value must be reassessed to assure its applicability for the proposed usage. It may be used without restriction for Category III mission burden estimates.

REFERENCES: PQAP Review, September 28, 1971, Denver, Colorado.

_____ _____

Planetary Protection Officer Date

PARAMETER TITLE: Surface Microbial Density (d_S (0))

VALUE	
UPPER	
ACCEPTABLE	See Below
LOWER	

APPLICATION	
MISSION	All
CATEGORY	III, IV
PLANET	All

PARAMETER DEFINITION: The average number of microorganisms on any free surface (non-encapsulated) of a spacecraft system, subsystem, assembly or subassembly.

APPLICABLE SOURCE: All fallout burden on the spacecraft (exposed and mated).

CONSTRAINTS: Values of this parameter are selected from the following categories, depending on the manufacturing process and cleaning and contamination control procedures for the designated hardware:

Clean room 10^4 or better - highly controlled	$500/m^2$
Clean room 10^4 - normal control	$5x10^3/m^2$
Clean room 10^5 - highly controlled	$1x10^4/m^2$
Clean room 10^5 - normal control	$1x10^5/m^2$
Uncontrolled manufacturing	$1x10^6/m^2$

For estimating spore surface densities (for purposes other than to establish terminal sterilization cycles), use 10% of the above values.

Planetary Protection Officer	Date

PARAMETER TITLE: Temperature Dependence of D-Value (Z)

VALUE	
UPPER	21^{O}C
ACCEPTABLE	21^{O}C
LOWER	21^{O}C

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: The change in temperature which produces a factor of 10 change in a given D-value.

APPLICABLE SOURCE: All microbial burden subjected to dry heat sterilization cycles.

CONSTRAINTS: Applicable within the temperature range of 100^{O}C to 125^{O}C. Applicable to dry heat sterilization cycles meeting requirements of NPG 8020.12B.

REFERENCES:

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

Planetary Protection Officer	Date

PARAMETER TITLE: D-Value for Bioburden on Exposed Surfaces (D_{S125})

VALUE	
UPPER	0.5 hr.
ACCEPTABLE	0.5 hr.
LOWER	0.5 hr.

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Time required to destroy 90% of the microbial spore population on surfaces subjected to sterilizing dry heat at a temperature of 125^{o}C at an absolute humidity corresponding to a relative humidity of less than 25% referenced to the standard conditions of 0^{o}C and 760 torr pressure.

APPLICABLE SOURCE: All microbial spore populations located on spacecraft surfaces such that gas exchange can take place.

CONSTRAINTS: Specified D-value can be applied where sterilization cycle conditions stated in NPG 8020.12B have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

REFERENCES:

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

Planetary Protection Officer	Date

PARAMETER TITLE: D-Value for Bioburden on Mated Surfaces (D_{M125})

VALUE	
UPPER	1.0 hr.
ACCEPTABLE	1.0 hr.
LOWER	1.0 hr.

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Time required to destroy 90% of the microbial spore population on mated surfaces of spacecraft subjected to sterilizing dry heat at a temperature of 125^{o}C at an absolute humidity corresponding to a relative humidity of less than 25% referenced to the standard conditions of 0^{o}C and 760 torr pressure.

APPLICABLE SOURCE: All spore populations on mated surfaces of spacecraft.

CONSTRAINTS: Specified D-value can be applied where sterilization cycle conditions stated in NPG 8020.12B have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

REFERENCES:

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

Planetary Protection Officer	Date

PARAMETER TITLE: D-Value for Encapsulated Bioburden (D_{B125})

VALUE	
UPPER	5.0 hr.
ACCEPTABLE	5.0 hr.
LOWER	5.0 hr.

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Time required to destroy 90% of the microbial spore population encapsulated in non-metallic spacecraft material subjected to sterilizing dry heat at a temperature of $125^{o}C$.

APPLICABLE SOURCE: All spore populations buried within non-metallic spacecraft materials.

CONSTRAINTS: Specified D-value can be applied where sterilization cycle conditions stated in NPG 8020.12B have been met. Thermal response of materials must be considered in design of sterilization cycles. Project must specify method for the measurement of these parameters and make allowances for stabilization times.

REFERENCES:

1. Recommendations of PQAP Subcommittee 1A Resulting from Deliberations on July 25-26, 1968.

Planetary Protection Officer	Date

PARAMETER TITLE: Minimum Number of Spores per Assay (n_{min})

VALUE	
UPPER	
ACCEPTABLE	$\frac{1}{250}$
LOWER	

APPLICATION	
MISSION	All Requiring Terminal Sterilization
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: The minimum number of spores per surface samples assayed acceptable in determining the minimum terminal sterilization cycle.

APPLICABLE SOURCE: All spacecraft surfaces.

CONSTRAINTS: The number of surface samples obtained per assay will be as specified in individual project microbiological assay plans per NPG 8020.12B. Typically, for spacecraft in the 50 - 500m^2 range, there will be approximately 250 surface samples (each about 25 cm^2 in area) taken per assay. For this class of spacecraft, if all the surface samples used in the assay are negative, an assigned value shall be used for purposes of determining the minimum terminal sterilization cycle. This assigned value shall be one viable spore per total number of surface samples used in the assay.

REFERENCES:

1. Minutes of Meeting of Viking Terminal Sterilization Process, Martin Marietta Corporation, Denver, December 11, 1973.

Planetary Protection Officer	Date

PARAMETER TITLE: Fraction of Hardy Organisms and their Survival of Nominal Sterilization Cycles (N_H/N_0)

VALUE	
UPPER	1×10^{-3}
ACCEPTABLE	See Below
LOWER	1×10^{-4}

APPLICATION	
MISSION	Any Requiring Sterilization
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Hardy (heat resistant) organisms as a fraction of the total spore population on spacecraft surfaces. Survival of the hardy organisms is expressed as the ratio of the hardy organisms surviving a nominal sterilization cycle to the initial pre-sterilization total spore population.

APPLICABLE SOURCE: All microbial spore populations located on spacecraft surfaces.

CONSTRAINTS: Hardy organisms comprise a fraction of 1×10^{-3} of the total spore population on spacecraft surfaces. For nominal sterilization cycles, i.e., 35-50 hours at temperatures of 111^{o} - 125^{o}C, the surviving fraction of hardy organisms is 1×10^{-4}. Therefore, in designing or assessing spacecraft sterilization cycles, the logarithmic death-rate model based on the D and Z values provided elsewhere in this specification book should not be used to predict lethality greater than 1×10^{-4} for microbial spore populations on spacecraft surfaces. The model is valid, however, for calculating lethality up to the level of the hardy surviving fraction, which, at 1×10^{-4}, establishes the maximum allowable lethality for the nominal sterilization cycles described above.

REFERENCES:

1. Thermal Resistance of Naturally Occuring Airborne Bacterial Spores. J. R. Puleo, et al., Planetary Quarantine Laboratory, Jet Propulsion Laboratory, Cape Canaveral, Florida, 1978.

2. Statistics of the N_H/N_0 Ratio. Paper presented at the "Hardy" Organisms conference, Ames Research Center, November 1974, by P.D. Stabekis, Exotech Research & Analysis, Inc., Gaithersburg, Maryland.

Planetary Protection Officer	Date

PARAMETER TITLE: Time-Temperature for Sterility (K (†T))

VALUE	
UPPER	= 0.5 sec @ = 500^{O}C
ACCEPTABLE	Same
LOWER	Same

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: The short time-high temperature conditions at which all organisms will be completely destroyed.

APPLICABLE SOURCE: Any source of terrestrial organisms associated with spacecraft hardware. Sources can be encapsulated, mated surface, open surface or airborne. The temperature must exist at the location of the microbial burden for the required time duration.

CONSTRAINTS: Spacecraft organisms and their associated environment must reach a temperature of at least 500^{O}C and must remain at this temperature for at least one half second. This specification was derived from high temperature sterilization tests of microbial contamination.

REFERENCES:

1. Hoffman, R. K., et al. Thermal Inactivation of Aerosolized Bacillus subtilis var. niger Spores. Appl. Microbiol. 22(4): Oct. 1971.

2. Recommendations of PQAP, meeting held Feb. 1, 1973, New Orleans, LA.

Planetary Protection Officer	Date

PARAMETER TITLE: Probability of Surface Organisms Surviving Ultraviolet Radiation (P (uv))

VALUE	
UPPER	1
ACCEPTABLE	See Below
LOWER	$< 10^{-4}$

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: Probability that a randomly selected organism exposed to extraterrestrial ultraviolet radiation will survive the dose applicable to the mission specific conditions.

APPLICABLE SOURCE: All organisms exposed to extraterrestrial ultra-violet radiation.

CONSTRAINTS: Selection of a particular value is to be made in two steps as follows:

1. Assuming complete exposure of the microorganisms, i.e., no shielding, P(uv) is determined by the function described below. The value of P(uv) as a function of time is a straight line on a log-log scale. For Martian missions, the line is defined by the following two points:
   (a) P(uv) = 1 for a time of exposure of 1 minute, or less, and
   (b) P(uv) = 1×10^{-4} for a time of exposure of 1 hour.
   P(uv) for times of exposure other than the above can be obtained by interpolation or extrapolation of these two points. For distances other than for Mars (1.5A.U.), the time of exposure needed shall be scaled by an inverse square relationship.

2. The value obtained in accordance with the above must be increased to allow for the effects of shielding by structures or by small particles such as dust and debris.

REFERENCES: PQAP Review on January 18-19, 1972 at Cape Kennedy, Florida.

Planetary Protection Officer	Date

PARAMETER TITLE: PP Priority for Target Bodies

VALUE	
UPPER	
ACCEPTABLE	See Below
LOWER	

APPLICATION	
MISSION	All
CATEGORY	IV
PLANET	All

PARAMETER DEFINITION: The planetary protection status of each extraterrestrial solar system body, which taken together with the mission plan specifies the category of a spacecraft mission.

APPLICABLE SOURCE: N/A

CONSTRAINTS: The PP priorities are given in the table below. For celestial objects not explicitly listed, priority B may be assumed. The category of a mission is subject to PPO approval.

PP PRIORITY		
A	B	C
Sun Moon Mercury	Venus Jupiter Saturn Uranus Neptune Pluto outer planet satellites (except Europa) comets asteroids	Mars Europa (tent.)

Planetary Protection Officer	Date

PARAMETER TITLE: Orbital Lifetime, Mars

VALUE	
UPPER	See Below
ACCEPTABLE	See Below
LOWER	See Below

APPLICATION	
MISSION	Orbiter
CATEGORY	III
PLANET	Mars

PARAMETER DEFINITION: Date prior to which Category III spacecraft, or subsystems thereof, intended to orbit Mars shall not impact the planet, to the probability of impact specification.

APPLICABLE SOURCE: Those associated with orbiter spacecraft or orbiting portions of other mission types.

CONSTRAINTS: Orbit characteristics shall be such that P_{I},max for the mission shall be met until twenty years from the launch of the mission. Between 20 and 50 years from launch, the spacecraft shall remain in orbit with an assurance ≥ 0.95.

All Mars orbiter spacecraft which do not satisfy these requirements must comply with a total bioburden (surface, mated, and encapsulated) requirement of $5x10^5$ spores.

_____	_____
Planetary Protection Officer	Date

PARAMETER TITLE: Maximum Surface Bioburden for Category IV Missions to Mars (Except Lander Systems with Life Detection Experiments)

VALUE	
UPPER	
ACCEPTABLE	= 300 bacterial spores/m^2 = 3.0×10^5 bacterial spores/ vehicle
LOWER	

APPLICATION	
MISSION	Lander, Probe, Orbiter
CATEGORY	IV
PLANET	Mars

PARAMETER DEFINITION: This specification establishes a maximum limit on the exposed surface bioburden for all category IV missions to Mars except lander systems with life detection experiments.

APPLICABLE SOURCE: Exposed exterior and interior spacecraft surfaces.

CONSTRAINTS: The surface bioburden for each Category IV orbiter, probe, or lander system* shall be an average of = 300 bacterial spores per square meter, and the total vehicle surface burden shall be = 3.0×10^5 bacterial spores, as measured by microbiological assay processes and techniques used for establishing the burden levels on the Viking landers and orbiters (Ref. 1), or other improved assay methods. It shall be incumbent on the project to demonstrate equivalence for techniques other than those used on Viking.

The burden levels specified apply to organisms on the orbiter, probe, or lander system at launch. No allowance shall be made for burden reduction factors that may be associated with inflight or surface conditions on Mars (vacuum, UV, temperature, etc.)

* A lander system is defined as all subsystems included in a single landing event.

REFERENCES: 1. Viking ‘75 Program Microbiological Assay and Monitoring Plan, Viking ‘75 Project, M75-148-0.

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Planetary Protection Officer Date